

A simple circular polarizer for 10GHz

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ABSTRACT: A simple polarizer based on Ku-band satellite TV hardware (orthomode couplers and feedhorns) and a dielectric delay plate, suitable for 10GHz EME is described. The main goal was a no-tune design that can be easily reproduced without measuring equipment, but still achieves high quality

1. INTRODUCTION

For a long time, the only serious argument against use of circular polarization for EME has been that, for a typical radio amateur, it is difficult to achieve good circular polarization. This was based mainly on the experience with screw polarizers, which indeed require careful tuning with suitable measurement equipment, and linear orthomode plus 90 degree hybrid combinations, where the connecting cables have to be made with high precision and are prone to losses etc.

However, a few years ago, when Zdenek OK1DFC introduced the septum polarizer to the amateur radio Moonbounce community [1], this changed dramatically. Now everybody with moderate metal working skills (cutting sheet metal to measure and joining a few such pieces) could build a working no-tune circular polarizer, with separate ports for left and right hand circular polarizations.

While the septum can still work perfectly on 10GHz and higher, the dimensions become a bit small for precise cutting with hand tools. So for a long time I had the idea of using Ku-band satellite TV components like orthomodes, feedhorns etc. and design a feeding system based on them. At the 02 EME conference in the Czech republic, SM6CKU gave me an orthomode/feedhorn combination and I promised to design a polarizer for it.

2. TRANSITION - POLARIZER - FEEDHORN...

There seems to be a widespread confusion among HAMs about what is a "dish feed"! Most published "recipes" are in fact what should be called a "feeding system", because they join together several independent components. In a well designed feed, these should be independent of each other. There is no such thing as a "septum feed"! We only have a septum polarizer, which can be used as a part of a CP feeding system.

For example a linear polarized VE4MA design combines three parts:

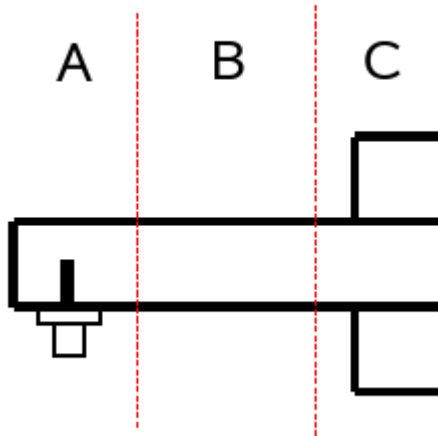


Fig 1. The VE4MA feed: A = transition, B = waveguide, C = radiator

First comes the coax to waveguide transition "A", which must bring the EM wave from the coax cable into the waveguide in a well matched way. This is its only task - in a well designed feed it has no effect on the directional pattern. Another way of bringing the wave into the round waveguide could be used here (for example a rectangular/round WG transition) without affecting the pattern.

Then comes a section of waveguide "B". On first sight, this does not seem to be important/necessary, but it serves to suppress any higher modes that could have been launched by the probe in the coax/WG transition. Such modes could distort the radiation pattern of the feedhorn, if they would arrive at the aperture. The attenuation of below-cutoff modes in a waveguide is extremely high, so a very short section is enough to prevent this from happening. It is the task of this section to assure that the coax/WG transition and the feedhorn are really independent of each other. In a well designed system, its length should not be important, provided it is long enough to kill the higher modes. However in HAM practice, there usually is some interaction among the parts. Most often, the radiating section is not well matched and some reflection happens there. This is usually compensated by detuning the coax/WG transition. In this case, the length of the WG section is important, since the reflections at the transition and aperture must cancel out.

And last but not least, comes the radiating structure "C", the real feedhorn, in the VE4MA case a parasitically excited coaxial resonator. This determines the radiation pattern of the feed - and the pattern will be always the same, regardless of how you have excited the (fundamental mode) field in the waveguide. Again, a different radiating section (for example

W2IMU) could be used here to get a different pattern.

Even with a "coffee can feed", there is a "radiating section" which can be treated separately, namely its aperture.

For a circular polarized antenna, we have to add another component, the polarizer:

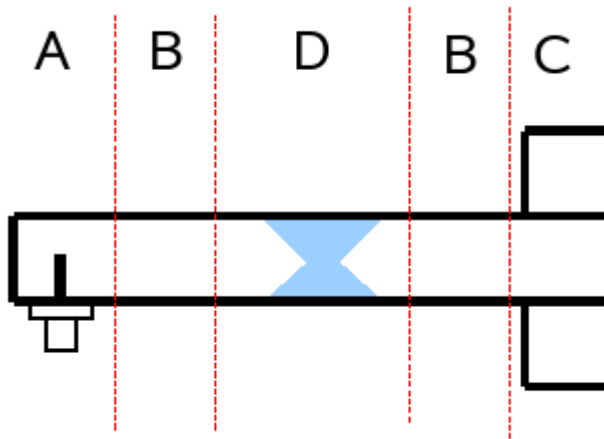


Fig 2. A circular polarized feed: A = transition, B = waveguide, C = radiator, D = polarizer

Again, in a well designed system this component should be independent of the others, so any type of polarizer can be used with any type of radiator. (The original OK1DFC version of septum has square waveguide output, so another component, a square to round transition, must be added if standard feedhorns based on round waveguide are to be used.)

3. Ku-BAND SATELLITE COMPONENTS

Modifying Ku-band LNBS into 10GHz low noise preamplifiers has a long tradition among microwave HAMs. But there exists a whole bunch of other Ku-band components often available for cheap at fleamarkets and general junk, that could be abused for HAM purposes on the 10GHz band:

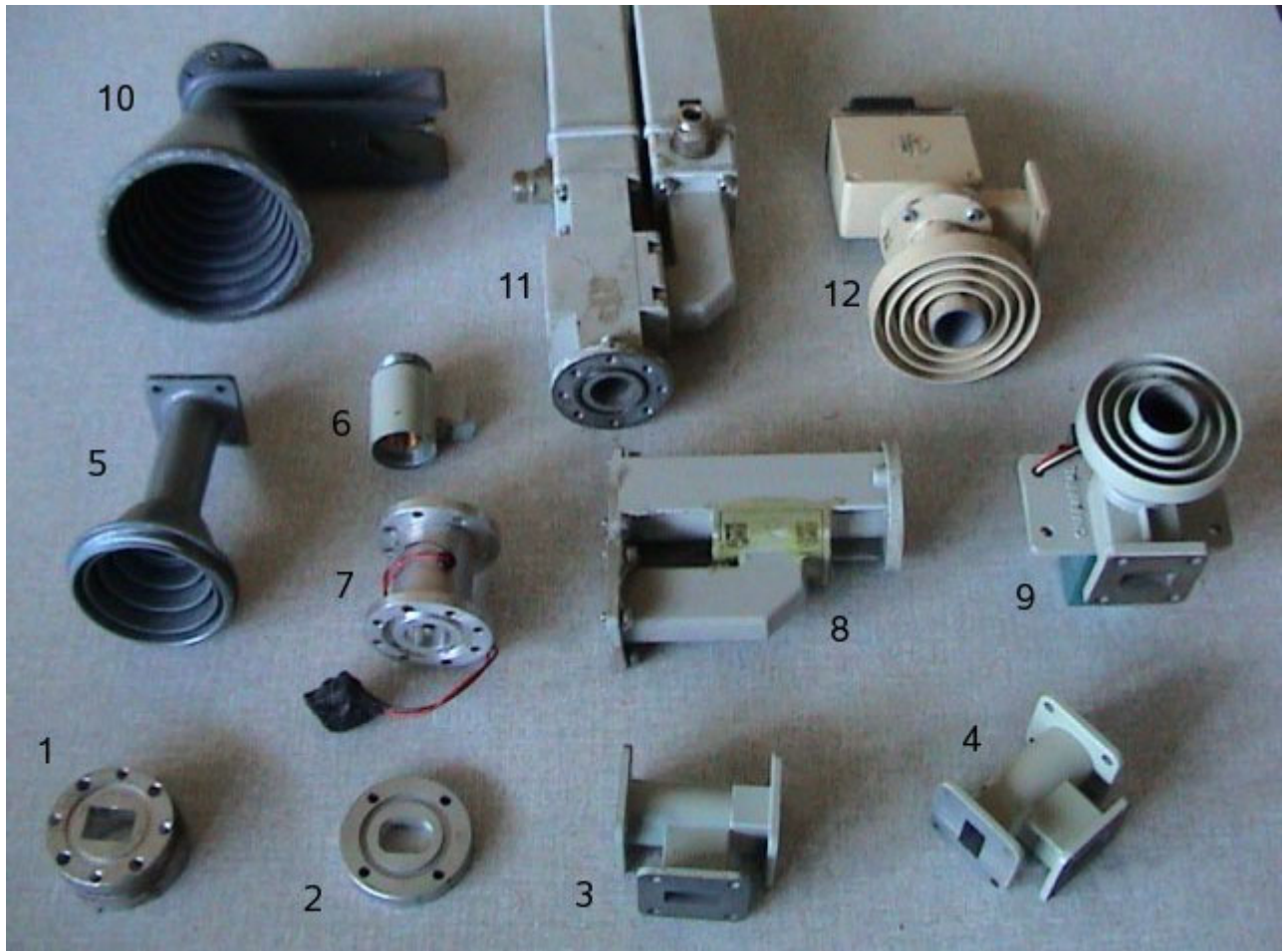


Fig 3. 1 = two stage rectangular/round transition; 2 = single stage rectangular/round transition; 3,4,8: linear orthomode couplers; 5: feedhorn for offset dish; 6,7: ferrite polarizers; 9,12: mechanical polarizers with feedhorns for central fed dish; 10 feedhorn for Gregorian system; 11: linear orthomode with two LNBS.

They all use R 120 (WR-75) rectangular and 19mm diameter round waveguides. (Strangely, this is not a standardized size for round waveguides! For example C104 (WC80) for 10-13.7GHz is 20.24mm and C120 (WC69) for 11.6-15.9GHz is 17.475mm)

The idea here is to use a satellite linear orthomode coupler and add a simple circular polarizer. This way we get a circular ortho, with two separate R 120 ports for left and right hand polarization.

4. THE DIELECTRIC PLATE POLARIZER

A circularly polarized wave can be thought of as two linear polarized mutually perpendicular (for example, at + and - 45 degrees) waves with 90 degrees of phase offset:

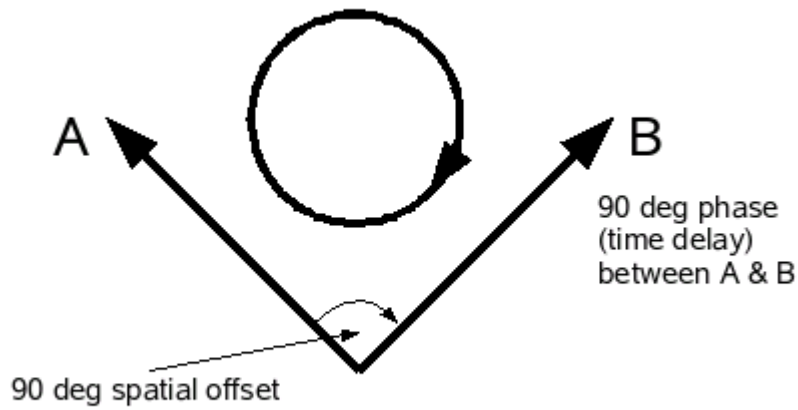


Fig 4. Making a circular wave from two linear ones

A linear vertically polarized wave can also be thought of as a sum of two perpendicular linear waves at + and - 45 degrees, but with zero phase offset:

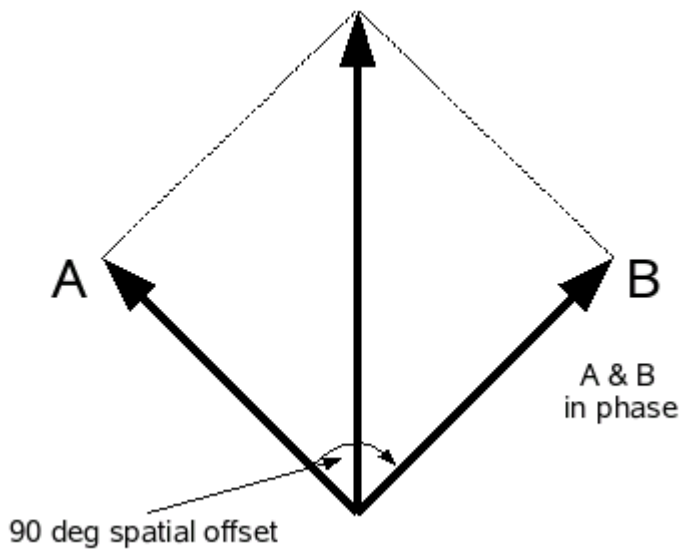


Fig 5. Making a linear wave from two linear ones

Looking at the pictures above, one can easily see that all that has to be done to change fig 5 into fig 4 (linear into circular) is to delay one of the 45 degree components 90 degrees in

phase, relative to the other.

There are several ways to achieve this, for example two rows of screws at 45 degrees, or a waveguide that has different dimensions (and hence different propagation speeds) in the two 45 degree planes - a squeezed tube [2].

Another way is to load the waveguide with dielectric in a suitable way, for example by putting a sheet of dielectric material into the waveguide at a 45 degrees angle to the incoming linear polarization [3].

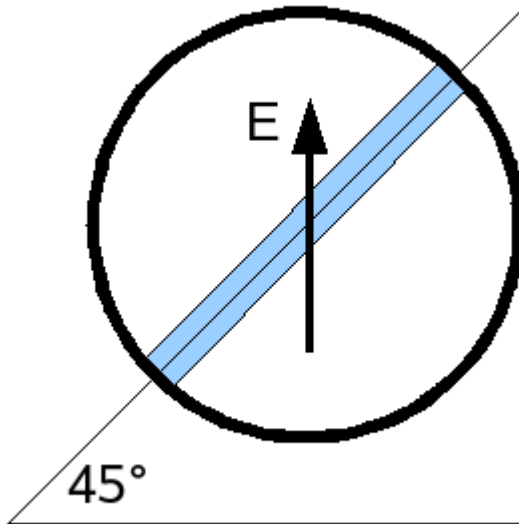


Fig 6. A dielectric plate polarizer (blue) in a round waveguide

Doing this, one has to be careful not to cause too much reflections in the waveguide. An old rule of waveguide plumbing says: do things gradually to reduce reflection. Following this rule, the dielectric plate is shaped like this:

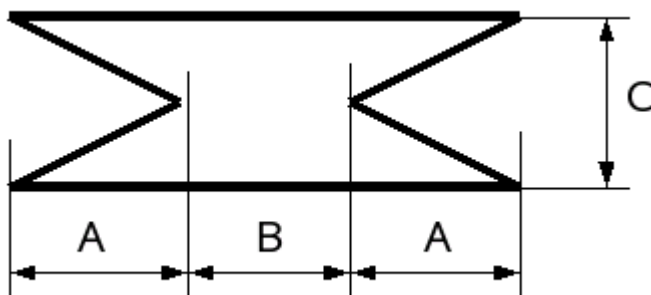


Fig 7. The shape and dimensions of the dielectric plate

Of course the dielectric material used must be of low loss at the operating frequency. First thing that comes to mind is PTFE, but it is soft (doesn't keep shape very well) and it is hard to glue into place. I did first experiments with PTFE but then changed to PMMA ("plexiglass").

Loss wise it is no worse than PTFE (negligible losses in both cases), but its hardness is "just right", easy to cut and file while stable in form. Easier to glue, too.

I've designed the 10.4GHz version to fit into the 19mm round waveguide used by the satellite TV industry. Individual pieces will differ in diameter by a few tenths of a mm. I suggest filing the plate so that it fits tightly, this way it might not even be necessary to glue it in. On the feedhorn given to me by SM6CKU, the bore is somewhat conical, (a requirement of the casting / molding process?) so the plate nicely "wedges" into position.

I made the plate by first cutting it out with a jigsaw, making it slightly bigger than required, and then filing it to measure. The dimensions for 4.3mm thick PMMA are A=16mm, B=11mm, C=19mm. To get better than 1dB axial ratio, the tolerances should be within 0.5mm - not too hard to achieve. Drawing a template on mm paper can help here.

The 45 degree angle at which the plate has to be placed into the waveguide is quite critical, should be within a couple of degrees.

5. RECEIVER PROTECTION

The R 120 flange on the satellite ortho is ideal for a modified LNB type preamplifier. However, the isolation between the ports is typically around 20dB, not enough to protect the LNA from the EME transmitting power levels.

A simple zero-loss receiver protection switch can be made by simply inserting a metal pin into the RX waveguide using a spring loaded solenoid coil:

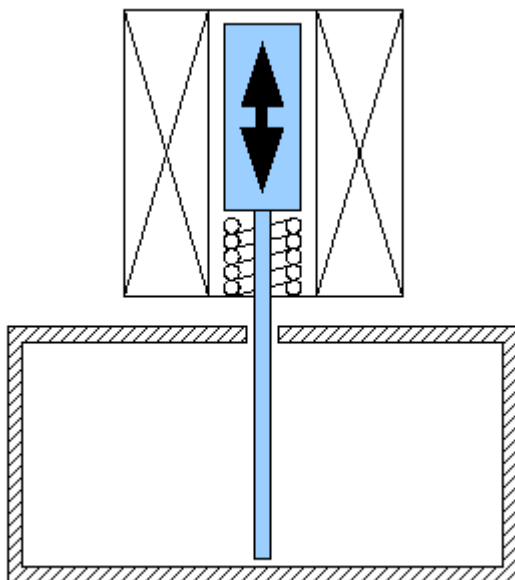


Fig 8. A simple way to protect the receiver

Solenoids from old relays, washing machine valves, etc can be used. 20..30dB can be achieved even without the probe having contact with waveguide walls. Together with the port isolation, this gives a comfortable margin for receiver protection.

6. BUT I HAVE HEARD THAT CIRCULAR POLARIZATION IS WORSE FOR EME...

There were rumors of this kind circulating around the EME community, but they aren't true.

In my paper at the 2000 EME conference in Rio [4] I have described at length why circular is better. At that time I did not yet know about the differential depolarization at the Moon, so let's take a look at that.

Luckily, WA5WJB has put some hard to find old lunar radar papers online (most relevant is [5]), so we can see what empirical measurements have shown.

When superficially looking at these papers (for example seeing figure 4 in [5] without reading the fine print below it) one can really get the false illusion that there is a problem with circular.

But reading them carefully, going through the math and numbers, one can see that this is not the case.

So, in short, what can be concluded from these papers?

Relevant for our discussion are the differences in depolarization between linear and circular, which are described there.

As can be seen from figs 5 and 7 in [5], this happens predominately at the outer rim of the lunar disk, where the incidence angle is above 45 degrees ($\cos < 0.7$ in the above mentioned figures).

In that area the polarization ratio is cca 7dB (83% vs 17%) for linear and 3dB (50% vs 50%) for circular. This means 0.8dB of loss for linear vs 1.8dB for circular. That would be a 1dB advantage for ALIGNED linear (I've shown in my Rio paper [4] that in a typical EME situation, polarization is almost never aligned, causing on average more than 1 dB of loss).

But these numbers hold only for the outer limb of the Moon, which only contributes a small part of the echo.

Integrating the 3.8cm numbers in table 1 from [5], (see spreadsheet [6]) one can see that this outer part (>45 degrees) contributes only cca 20% of the total returned echo.

Weighing the depolarization curves in figs 5 and 7 of [5] with the values from table 1 from the same paper, one can estimate that the effective depolarization ratios of the whole Moon are cca 9.5dB (89% vs 11%) for linear and 8dB (86% vs 14%) for circular. This is 0.5dB vs 0.65dB loss for linear and circular, respectively. This means that the "circular depolarization penalty" is only 0.15dB!

Obviously, the "circular depolarization penalty" is significantly smaller than the "linear nonalignment penalty", as I described my Rio paper.

And more than that - the 0.15dB signal deficit is of the diffuse part from the rim, which contributes most of the Doppler broadening!

This means that the "good signal" (specular part from the center of the lunar disk) vs "bad signal" (Doppler broadened diffuse part from the rim) ratio is BETTER for the circular polarization!

Ergo: IT MAKES A LOT OF SENSE TO USE CIRCULAR POLARIZATION FOR EME!!

7. CONCLUSION

Being a very lazy person myself, I can understand that people who have working linear systems are reluctant to make modifications on them, therefore they do not like the idea that others would go circular. However experimenting with and modifying our hardware should be a part of the hobby, shouldn't it?

Personally, I have both linear and circular feeds for my dish, so I have no vested interest here. But from own operating experience, I know that linear stinks...

8. REFERENCES

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